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A development of ecological risk screening with an application to fisheries off SW England.

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Abstract

A development of the ecological risk screening (ERS) technique, Scale Intensity and Consequence Analysis (SICA), is described and application to the varied fisheries and ecosystem off the southwest of England on behalf of an industry steering group (SG) is summarised. The purpose was systematically and consistently to prioritise ecological risks in relation to policy goals agreed by the SG. Scientists listed and advised on ecosystem components, their units (individual species, habitats, or communities) and attributes, as well as agents of change in the SW, their activities and generalised effects relevant to the policy goals. A working group (WG) of fishers, fishery observers, technical advisors and marine scientists paired each unit with the activity thought most likely to impact the most sensitive policy goal, then scored risk according to defined rules spatially, temporally, and as intensity and duration of effects. The geometric mean of the four scores, slightly adjusted for unscored factors if necessary, was the relative impact score (RIS). With this standardised method, the main aspects of risk were considered separately and independently thereby assisting objective prioritisation. Nineteen unit-activity pairs were listed as priority risks (RIS>3) in the SW region during a 2-day meeting that fully exploited the wide range of information and experience available at the WG. Socio-economics was not considered by the WG. The ERS for the SW was designed to be compatible with other similar ERSs that might be carried out for neighbouring marine regions. ERS can minimise extra monitoring needed for ecosystem management and, in principal, collaborating non-fishery agents of change could be included. By engaging all stakeholders in the setting of initial priorities for action and by assembling all available sources of information, ERS offers a useful starting point for holistic ecosystem management.

Keywords

Ecological risk screening, ecological risk assessment, SICA, EAF, EBFM, England (SW), English Channel, Celtic Sea

Introduction

Attempts to manage large aquatic systems can quickly become swamped by data describing the states of fisheries and other agents, the many species, physical habitats and communities present, and the ecological processes binding them all together. Although various multivariate methods are available to deal retrospectively with large numbers of indicators (see table 3 in Cotter et al., 2009), a more purposeful and efficient strategy is to (i) decide policy goals for the aquatic system, (ii) use a comprehensive screening process to weed out the controllable activities of man posing least risk to achievement of those goals, then (iii) to monitor only those indicators needed to inform about the state of the system in relation to the remaining, principal risks. In this way, monitoring can be more economical, interpretation of indicators is more direct, and the list of managerial action points can be shorter and more pertinent. Fletcher et al. (2005) describe a similar approach.

Methods for screening large numbers of possible ecological risks posed by fisheries have been developed in Australia (Astles, 2008; Scandol et al., 2009). We refer to them collectively as ecological risk screening (ERS) methods within the wider field of ecological risk assessment (ERA) (Burgman, 2005). They include (i) the national ecologically sustainable development method (Fletcher, 2005); (ii) scale intensity and consequence analysis (SICA) which is level 1 of the hierarchical, ecological risk assessment of the effects of fishing (ERAEF) (Hobday et al., 2007); and (iii) qualitative ecological risk assessment (QERA) (Astles et al., 2006). All of these methods involve subjective but systematic discussions of lists of potential ecological issues with respect to agreed policy goals at a working group of interested and informed people. The methods can be ecologically comprehensive, make use of all available sources of information – including publications, theses and advice from specialists – and can directly engage stakeholders thereby boosting their acceptance of the findings (Fletcher, 2005). The policy goals might originate from government, international conventions, or from a politically relevant local group.

Despite their merits, three concerns with ERS methods may be impeding wider adoption. One is how to choose between the three competing methods that use different concepts of risk and other terms (Astles, 2008; Scandol et al., 2009). Another is that ERS depends too much on the subjective decisions of the people involved. A third is that risk scoring methods are not yet standardised and may be too imprecise. They include a 5-compartment risk matrix (Astles et al., 2006), the product of ranked consequence × ranked likelihood (Fletcher, 2005), and separate spatial and temporal scoring of the worst case for each component that feeds flexibly into an intensity score "judged based on the scale of the activity, its nature and extent" (Hobday et al., 2007, p. 61).

Our interest in ERS was motivated by fishers and processors based in the SW of England who had been asked to respond to questions from fish retailers about possible over-fishing and ecological damage associated with the various different fisheries operating from ports in Cornwall, Devon and Somerset (figure 1). Details of the fisheries are given elsewhere (Cotter et al., 2006; Walmsley and Pawson, 2007). Five teleost species found in the SW (cod, plaice, Dover sole, whiting, and haddock) received full, annual analytical assessments for management under the European Common Fisheries Policy (CFP) but the results were too focused to answer the general ecological questions being asked. Fishery certification schemes, for example by the Marine Stewardship Council, might have provided fuller answers but fishers were concerned about the delays and costs of certification. ERS was proposed as a more immediate and cost-effective solution.

This paper presents a development of ERS derived from SICA and implemented on behalf of a steering group (SG) of fishers and fish processors operating in the SW. The primary aim was to prioritise systematically and consistently the main ecological risks posed by fishing in the SW and, if possible, by other agents operating there, taking into account any adjusting factors such as existing management measures. The SG and other stakeholders would then be better informed to discuss with fish retailers which risks needed action and which were relatively unimportant. A secondary aim was that risk scoring should link compatibly across neighbouring marine regions thus leaving the way open to apply ERS elsewhere around Britain. The ERS scores were not intended to be linked with specific prompts for management actions as has been described in other applications (Fletcher, 2005).

Our ERS working group (WG) met for 2 days, in October 2013. Relative risks were decided for many ecological components with the new ERS method though not for all of them because of the limited time and, sometimes, lack of information. The available results, reported fully elsewhere (Seafish, 2014a), are briefly summarised to indicate the scope and output of discussions. The opportunity to extend our work was not available so this paper cannot discuss indicators or monitoring in depth. Our use of ERA terms, highlighted in italics at the first occurrence below and summarised in table 1, mostly follows Hobday et al. (2007).

Methods

Initially, the industry SG was invited to discuss and agree (i) the boundaries of the SW marine ecosystem, (ii) the fisheries to be included in the risk assessment, and (iii) the top-level principle and policy *goals* for management of the region. We explained that their choices would govern the whole ERS process by allowing scientists to decide which *effects* of fishing might be contrary to their chosen policies and, later, if and when opportunities permitted, to set detailed *operational objectives* (OOs) and *indicators* for monitoring progress of the ecosystem towards the desired states (Fletcher et al., 2005; Hobday et al., 2007, 2011).

Scientific specialists prepared short background reports on each of the main ecological *components* of the SW system describing (i) its ecology and distribution, (ii) the current states of individual stocks or other sub-groupings of populations in relation to recognised reference points or conservation objectives, (iii) known effects of SW fisheries on the component, (iv) measures known to mitigate the effects of fishing, and (v) any other *agent of change* (or just '*agent*') or conservation issues relevant to the component. The reports were circulated to members of the ERS WG.

The Seafish team (WL, AC, MP, JC) prepared other essential documents in advance of the WG. We listed components and *units of analysis* ('*units*') but differed from current Australian practice (see http://www.afma.gov.au/managing-our-fisheries/environment-and-sustainability/ecological-risk-management/) in not using separate components for target, discarded, and byproduct species, or for protected, endangered and threatened (PET) species. In this way, our lists were independent of varying fishery practices and conservation priorities. For species distributed as separate, recognised stocks one of which was local to the SW region, the stock, not the species, was equated with the unit affected by SW fisheries. The effect of this decision was to raise spatial scores, see below. Generalised *attributes* of units, e.g. abundance, were also listed. Background information describing the fisheries selected by the steering group was taken from regional reports (Cotter et al., 2006; Walmsley and Pawson, 2007), from ICES fish-stock WG reports, from a European database on fishing effort (Scientific, Technical and Economic Committee on Fisheries of the European Commission), and from knowledgeable individuals taking part in the ERS WG. Maps of the spatial distribution of fishing grounds around the SW of England based on vessel monitoring (VMS) data from those fishing vessels > 15 metres in length were also available (Jennings and Lee, 2012). Agents and their *activities*, were listed based on knowledge of the fisheries and other activities occurring in the SW. Effects of activities were classified and named with the aim of creating mutually exclusive categories that were generally applicable, not just to fishing. The relevance of each effect was confirmed by linking it to the policy goals set out by the SG. A spreadsheet, with one sheet per component, was prepared for providing summary information to the ERS WG (table 2a).

The ERS WG met at Cefas, Lowestoft from 16-17 October 2013. Members included active fishers, advisors to the fishing industry, specialists on fishery bycatch and fishing gear, fishery scientists and marine ecologists. A flow diagram of the ERS method used is shown in figure 2. The most sensitive attribute of each unit was paired with the activity of the agent thought most likely to prevent achievement of the policy goal most likely to be impacted. This is referred to as a unit-activity pair. Other, lesser impacts were ignored, though one unit was sometimes paired with more than one activity to help decide which posed most risk to policy. Cumulative impacts from multiple activities or agents were likewise ignored; this was because of the potential complexities of dealing with them within a simple risk-scoring framework. The WG worked down the prepared lists of units with the help of the background reports, scoring all unit-activity pairs by consensus according to the uniform rules described below. This procedure, though time-consuming, was intended to diminish the influences of pre-conceived or stereotyped ideas about individual risks, as well as to draw out any special knowledge of WG members.

Our scoring approach differed from that recommended for SICA (Hobday et al., 2007). Firstly, we scored all pairings, not just the "worst case" for each component since the worst cases would have been difficult to agree for the SW without previously applying the systematic scoring system to all cases. Secondly, we did not always assign a high score when information was lacking, as recommended for SICA for precautionary reasons (Hobday et al., 2007). This would have led to a distracting profusion of high scores. Instead, we identified situations where more information seemed necessary, assigning a low score if that was our best understanding of the situation or, alternatively, postponing scoring of that unit-activity pair indefinitely in order to leave more time in the meeting to discuss the better-known risks. Thirdly, we used differently defined risk-scoring systems.

Each unit-activity pair was assigned a *relative impact score* (RIS), a new term proposed to emphasise the relative nature of scores more explicitly than variably defined terms with broad usage such as 'consequence' and 'risk'. The RIS was calculated as the geometric mean (4^{th} root of the product) of scores for spatial scale, temporal scale, intensity-of-effect, and duration-of-effect, each ranging from 0 to 5 and intended to contribute independent, non-overlapping information to the RIS. If any of the four scores was zero, the RIS, being a geometric mean, was also zero. For spatial, temporal and intensity scores, the guidance given to the WG was 0 = negligible, 1 = less than 10%, 2 = 10 to 20%, 3 = 20 to 50%, 4 = 50 to 90%, and 5 = 90 to 100%, where percentage (or corresponding fractional value) refers to the total area, total time, or maximum intensity of an effect, respectively. For duration scores, time frames typically relevant for management were used, see below. Non-integer scores were permitted to resolve disagreements. Spreadsheet columns used to store the four scores, RISs, and other choices made during the WG are shown in table 2b.

The spatial score was defined as *the overlap between (or, mathematically, the intersection of) the area of activity, the area occupied by the unit of analysis while the activity is occurring, and the SW region, expressed as a fraction of the total area occupied by the unit*. In figure 3a, this is usually the grey area divided by the area outlined with dots and dashes though it may sometimes be relevant to notice that, if the unit is migratory, the 'total area occupied' may be larger than the 'area occupied while the activity is occurring'. Using the total area occupied as the denominator meant that, if the unit occurred in nearby regions also subjected to ERS, the sum total of spatial scores across all the regions occupied by the unit should never exceed the maximum, 5, and spatial scores were then assigned proportionately among the regions. A 'high-mid-low' categorisation in spreadsheet column 5, 'SW stock as % of stated stock', see table 2a, was important for deciding spatial scores. In practice, most spatial scores could only be estimated crudely, partly because fished areas tend to be patchy and depend heavily on variable frequencies of fishing in outlying grounds (Jennings and Lee, 2012), and partly because areas occupied by a unit may also be patchy, poorly known, or depend on population size.

The temporal score was defined for any single year as *the overlap (or intersection) between the period when the unit of analysis occurs in the SW region and the period when the activity occurs there, expressed as a fraction of one year (or of the lifespan of the impacted life stage of the unit if less than one year).* In figure 3b, this is the length of the grey arrow as a fraction of the year (or of the vulnerable lifespan if less). The motivation for this definition was that the maximum temporal exposure of a member of a unit to an activity is continuously over its total lifespan though, by subdividing the time risk into years, the lifespan need not be known. Units whose impacted life stages live less than one year are exceptions in the definition. In contrast to the spatial score, the temporal score could range independently from

0 to 5 in different ERS regions occupied by a unit. This was intended to match the possibility for independent controls on activities in the different regions at any time of year.

By means of these definitions, our spatial and temporal scores were scaled in relation to the geographic domains and lifespans of the units. The two scores were thus based on measures with biological relevance not possessed by the absolute units (nautical miles, days) employed by SICA (Hobday et al., 2007); the intention was to improve the comparability of scores across different units. Both types of score contributed quantitatively to the calculated RIS whereas, in SICA, they merely provide background scores from which an intensity score (and thus the final 'consequence' score) is derived subjectively. Our view was that this subjective stage was unnecessary. A benefit of our method was that migrations could be allowed for simply:- a unit migrating through the SW region annually received a spatial score dependent on the total area occupied by the unit but received a temporal score dependent on the proportion of the year spent in the SW.

The intensity score was defined as *the proportion of the members of the unit of analysis affected by an activity where and when it occurs.* For example, if 25% of a fish species encountering a trawl are caught because the selectivity is 0.25, the assigned intensity score is 3 (between 20 to 50%, see above). The same score would result if 25% of the members of a species present are killed by a spill of a toxicant, or 25% of a habitat is smothered by a single dump of dredge spoil. The words "where and when it occurs" were intended to make intensity scores independent of spatial and temporal scores:- they could be high even though the activity rarely occurred in space or time, and *vice versa*. Our intensity score thus measured a third, independent aspect of impact and was preferred to the subjective intensity score of SICA.

A fourth aspect of ecological impact is the duration of an effect, of obvious relevance for questions of sustainability. We defined a duration score as *the duration of impact on the unit of analysis given that it has been affected and supposing that the activity has stopped.* So, for example, although the effect of mortality is permanent for affected members of a unit, the unit itself may recover. In the case of a species, community, or habitat with epifaunal structure, recovery would be by reproduction and growth of survivors. This idea is similar to 'productivity' in Productivity-Susceptibility analysis (PSA) (Stobutzki et al., 2001; Hobday et al., 2011) and 'resilience' in QERA (Astles et al., 2006). We preferred the term 'duration of impact (or effect)' because it covers non-living cases, for example when the physical structure of a habitat is at risk. The duration score is 0 if immediate recovery of the unit is expected and 5 if the effect is, for practical purposes, permanent. Intermediate duration scorings adopted by the WG were: 1 = several months, 2 = approximately 1 year, 3 = 1 to 3 years, and 4 = 3 to 10 years. A duration score was not used in SICA by Hobday et al. (2007).

Having calculated a preliminary RIS for a unit-activity pair, the ERS WG considered unscored factors that might reasonably adjust it, for example existing regulations, voluntary practices by fishers, extreme rarity throughout the range of a species, etc. The RIS was then reduced or increased by up to 0.5 units in the 0 to 5 scoring scale. Larger adjustments were not permitted so that the systematic scoring process would not be over-weighted by the subjective adjustment. Unless specified, 'RIS' refers to the final outcome of both scoring and adjustment. We followed the arbitrary suggestion of Hobday et al. (2007) that consequence scores – in our case, RISs – of 3 or above indicated risks worth investigating further for confirmation and, possibly, consideration by management.

Having found unit-activity pairs with high RISs, the WG briefly considered appropriate operational objectives, indicators and reference levels for them within the constraints of existing monitoring programmes which included market sampling of landings, observer surveys of catches on fishing vessels, and research vessel (RV) surveys. Precise specifications were deferred given that no new monitoring opportunities were foreseen at the time, and that many of the candidate indicators then available from fishery monitoring programmes would serve poorly for ecological monitoring.

Results

The industry SG defined the marine ecosystem (figure 1) and fisheries to be considered (table 3), and specified the top-level principle and policy goals to govern the ERS (table 4). The scale and geographic distribution of the fisheries in table 3 may have been affected by double counting, particularly of smaller vessels, because of movements between ports and changes of gear seasonally.

The ecological components and units chosen prior to the ERS WG are listed in table 5, together with the scientific reviews (Seafish 2014b) and other sources of information used. Proposals, accepted by the WG, for the agents and activities of most relevance, for possible effects categorised in relation to components and goals, and for standardised attributes and operational objectives are shown in tables 6, 7, and 8 respectively.

Units with RISs ≥ 3 are listed in table 9 along with the numbers of unit-activity pairs that were scored for each component, the policy goals (table 4) thought to be most at risk, other relevant issues, the best currently available indicators and operational objectives, and the adjusting factors considered. Unless stated, the RISs only relate to fishing activities; risks from non-fishing activities were mostly judged to be lower. Table 9 serves as the list of priority issues with respect to the policy goals in table 4. For a full presentation of the many detailed regional aspects considered, see Seafish (2014a), and for the completed scoring spreadsheet, see Seafish (2014c). The following notes supplementing table 9 point out issues thought most important by the WG, together with comments on possible indicators.

Marketable crustaceans

Long-term viability of crustacean fisheries was at risk (goal 1) because of poor knowledge of the biology and ecology of the local stocks, all of which were heavily fished by netters, potters and trawlers. Total landings, and spawners per recruit – as a proxy for maximum sustainable yield (MSY) – were chosen as indicators given that no more reliable measures of stock security were available from existing monitoring.

Marketable molluscs

Long-term viability of 3 molluscan fisheries was at risk (goal 1) because of low fecundities and high vulnerability of eggs to bottom trawlers. Heavy catches of scallops, *Pecten maximus*, by dredgers may have impaired their beneficial role in reducing phytoplankton populations and improving water clarity (goal 2) as has been observed for molluscan filter feeders elsewhere (Newell and Ott, 1999). Total landings and, for scallops, catches per unit of effort (CPUEs) from observer surveys were selected as the best currently available ecological indicators.

Elasmobranchs

Conservation concerns (Ellis et al., 2005; Dulvy and Forrest, 2010) were raised for 14 species of elasmobranch found in the SW region and fished by trawls,nets and lines (goals 1-4). Several spatial scores were high because of the importance of local stocks. Fisher sightings, or observer CPUEs were thought to be the best indicators available from current monitoring; a few species could be monitored by RV surveys in the SW.

Teleosts

Heavy fishing pressures, lack of scientific knowledge, and discarding put 14 species of teleost at risk (Goals 1-4). Spatial scores reflected the importance of local stocks. Some of these had benefited from management under the CFP but one, the pilchard, *Sardinia pilchardus*, was thought to be adversely affected by the low level of management practised in the SW. Fishing mortality (F) and spawning stock biomass (SSB), along with their reference points recommended by the International Council for the Exploration of the Sea (ICES), were accepted as indicators and operational objectives for those teleost species that received stock assessments. RV CPUEs were accepted for several others. Total landings was the only indicator available for 4 unassessed species not regularly caught by trawl surveys. Several non-commercial species were not considered because of lack of time.

Seaturtles

All five species of seaturtle occurring within the SW region were listed by the International Union for the Conservation of Nature (IUCN) but spatial scores were low because of the smallness of the SW region relative to their global distributions. Intensity scores were low for fishing because many interactions were thought to occur without a turtle being caught. Duration scores were high because of the low fecundity of sea turtles but only the leatherback, *Dermochelys coriacea*, received an RIS > 3 (goal 4) because of its vulnerability to floating polythene litter. The agreed operational objective was 'to avoid increasing the risk to global populations'.

Marine mammals

Two cetaceans, *Tursiops truncatus* and *Phocoena phocoena*, received RISs > 3 (goals 4) because they were the only known residents in the SW among several species of marine mammal sighted there, and they were repeatedly exposed to fixed nets and other fishing hazards. Goal 2 may also have been impacted if these species have a significant top-down regulatory effect on their local prey. The most practicable indicator was 'Sightings in the SW' using bycatch or other ongoing monitoring programmes.

Seabirds

None of the 24 seabird-activity pairs received RISs > 2.6 because of their wide distributions outside the SW and the rareness of significant mortalities of seabirds observed during fishing operations in the region. Some species may have been at risk from a possible reduction of small, surface-living fish within foraging range of nesting sites but others, such as gulls and gannets, were known to benefit from discarding. Breeding colonies of seabirds were regularly surveyed in the UK. The survey database might allow indicators and operational objectives to be set for monitoring the status of seabirds in the SW region.

Habitats

Although advisory papers (table 5) were received concerning habitats, the WG decided that there was insufficient time in the meeting to deal with them effectively. Special habitats were being considered by the UK's Marine Management Organisation, for example Maerl beds and Ross worm reefs. A general problem was that the extent and distributions of several types of habitat were not well known (Rice et al., 2012, section 3.1.2).

Communities

Demersal fish communities monitored with RV surveys using length-based indicators were given high spatial, temporal and intensity scores because they were treated as restricted to the SW region where fishing takes place throughout the year (goals 1-4). Duration-of-effect was also scored highly since fish communities are slow to respond to reduced fishing (Shephard et al., 2011). Non-disruption of the foodweb was suggested as the reference level for an operational objective for these indicators. Ichthyoplankton communities received high RISs because of reduced spawning by fished adults but this was merely a secondary aspect of the risks to adult fish communities. Three epibenthic communities were thought to have been affected by trawling and dredging (goals 2, 4) but four infaunal communities received lower RISs because these activities, though widespread, exerted a low intensity of effect on buried fauna. Other special and fragile benthic communities found in deeper waters of the SW region, e.g. pink seafan colonies, were not scored by the WG because of lack of time and information. An operational objective suggested for such communities was that the key species are successful according to an area- or density-related criterion. Zooplankton communities were considered vulnerable to indiscriminate predation by invasive species such as ctenophores and other 'jelly plankton' (Lynam et al., 2006; Bastian et al., 2011) but a high RIS was not thought justified given the open aspect of SW waters to the Atlantic. [See also a later paper on cnidarian jellyfish in the SW (Pikesley et al., 2014).] Phytoplankton communities can be vulnerable to coastal nutrient enrichment, possibly leading to increased frequencies of blooms but they were considered rare in the SW region because of the open, oceanic aspect, so RISs were low.

Discussion

The ERS reported here enabled a committee of people with a mix of skills and interests to review the many possible effects of fishing on the ecology of the SW region with "a disciplined and consistent approach" (Fletcher, 2005). Substantial detail was available from members of the WG on many species and their interactions with fisheries, on fishery regulations and bylaws, and on fishing tactics, gears and markets. Similar benefits of ERA were reported by Fletcher (2005) for Western Australian fisheries. As a general conclusion, the ERS usefully supplemented scientific advice provided by ICES for commercial species managed individually under the European Common Fisheries Policy. Since ERS finds priorities from among the, possibly, hundreds of concerns that might be raised about an aquatic ecosystem and, since it can productively involve stakeholders and tap all available sources of information, some form of ERS is likely to be a useful starting point for an ecosystem approach to management. Monitoring, research and, perhaps, short-term management actions then have an initial justification even if, later, calls are made to justify or adjust the priorities by more objective methods.

Our ERS method was intended to be objective and repeatable should a similar ERS ever be undertaken by a different WG, either to review our findings or as part of a repeating cycle to maintain and improve ecological awareness. Precisely defining the scoring methods set 'rules for the game' and is recommended because all unit-activity pairs can then be treated uniformly, scoring disagreements can sometimes be resolved by reference back to the definitions, and any political influences at the WG can be held in check. Independence of the four scores we used prompted the WG to deal with the main aspects of ecological risk (Marasco et al., 2007; Rice et al., 2012) seperately and without counting any of them more than once, thereby further helping to improve objectiveness. Spatial and temporal measurement scales were standardised in an ecological sense by measuring them in relation to total geographic distributions and life spans, respectively, rather than in terms of absolute units that may have different relevance for different units of analysis, possibly leading to incorrectly ordered spatial and temporal scores. Spatial scoring scaled risks in relation to area so as to assign conservation responsibilities fairly among different fishery regions. This is important in the UK where spatial management zones tend to be small relative to the distributions of many marine species. The option to arbitrarily adjust RISs by ± 0.5 satisfied the WG's wishes to alter slightly some RISs thought inappropriate because of unscored factors but, for the sake of objectivity, did not allow the main systematic scoring procedure to be rendered redundant.

Based on the adjusted RISs and the arbitrary cut-off of 3, a prioritised list of sustainability and conservation issues was prepared (Table 9). The effects of varying the cut-off on the issues brought forward could be explored, if required, by referring back to the WG spreadsheet. However, the cut-off should not be set too low if the RISs tend to be clustered at lower values because their ordering is then not dependable. The subjective basis of ERS, however rigorously it is carried out, implies that tight linkages between RISs and managerial actions should be avoided.

Future actions on priority issues identified by ERS were not discussed at the WG but might involve higher level assessments such as PSA and special modelling to confirm the risks found (Hobday et al., 2007, 2011). A danger, though, with this hierarchical approach is that the different levels utilise many of the same data and information and therefore are not independent (Hobday et al., 2011, p.380), implying that poorly determined RISs could be erroneously confirmed automatically by the more specialised studies. A better strategy is to seek new sources of information for new studies to confirm or explore high risks. A model-based approach to regional ecological risk assessment at a higher level than ERS is presented by Fock (2011).

When ERS is accepted to have been well informed and implemented, corrective actions might be agreeable for priority issues without further investigations. They might include voluntary changes or financial incentives to improve fishing practices, publicity to increase awareness of important problems, new local regulations or bylaws, organisation of fishers and observers to identify correctly and report sightings of rare species, as well as adjusted or specially designed monitoring if suitable indicators and operational objectives are available for units at risk. The ERS WG recognised that 'SMART' (Specific, Measurable, Attainable, Relevant, Time-bound) operational objectives are essential for effective monitoring of the status of units of analysis deemed to be at high risk (Fletcher et al., 2005). However, difficulties were experienced in identifying promising candidate indicators from the monitoring programmes then existing in the SW, mainly for the purpose of controlling landings of commercial species under the CFP. In this respect, the ERS helpfully provided a short list of units requiring indicators and monitoring if and when a more ecosystem-orientated approach is adopted for the SW.

Drawing up clearly stated policy goals (table 4) prior to the ERS WG allowed it to decide almost immediately whether or not the effect of an activity was acceptable with respect to that policy. This feature, taken from the Australian ERS methods, almost certainly helped the WG to avoid sterile political arguments about conservation-*versus*-commerce when discussing species or habitats of conservation importance. The policy goals for the SW had no legal status but, as they represented the views of the fishing industry, carried considerable political weight, particularly as they looked well beyond immediate commercial considerations and covered many peoples' aspirations for the future of the SW marine region. By contrast, a significant criticism of fisheries law under the European CFP was that policy was too imprecise for the effective guidance of management (EC, 2009).

Given additional funding for appropriate specialists, agents other than fisheries could be included compatibly in an ERS, for example gravel miners, offshore energy producers, and waste dischargers. This might enhance overall ecosystem management, though the activities at sea of many non-fishing agents are already regulated under UK and international legislation (Rees et al., 2006). ERS takes no account of the socio-economic aspects of exploiting aquatic systems, a basic feature of the ecosystem approach to fisheries management (FAO, 2003, 2005). Since an ERS WG already has a long agenda, socio-economic aspects would probably need a separate WG, allowing different professional advisors to be present. The two sets of advice could then be weighed against each other and translated into actions using a political or a reporting process. An example of the latter is described by Fletcher et al. (2005).

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References

Astles, K.L., 2008. A systematic approach to estimating ecological risks in marine fisheries. CABI Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources 3, 16 pp.

Astles, K.L., Holloway, M.G., Steffe, A., Green, M., Ganassin, C., Gibbs, P.J., 2006. An ecological method for qualitative risk assessment and its use in the management of Fisheries in New South Wales, Australia. Fisheries Research 82, 290–303.

Bastian, T., Haberlin, D., Purcell, J.E., Hays, G.C., Davenport, J., McAllen, R., Doyle, T.K., 2011. Large-scale sampling reveals the spatio-temporal distributions of the jellyfish Aurelia aurita and Cyanea capillata in the Irish Sea. Marine Biology 158, 2639–2652.

Burgman, M., 2005. Risks and decisions for conservation and environmental management (ecology, biodiversity and conservation). Cambridge University Press. 488 pp.

Cotter, A.J.R., Course, G.P., Ashworth, J., Forster, R., Enever, R., Goad, D., Bush, R., Shaw, S., Mainprize, R., Garrod, C., 2006. Summary of commercial fishing by English and Welsh vessels > 10 metres LOA for 2004. Scientific Series Technical Report No 134, Cefas, Lowestoft.

Cotter, J., Petitgas, P., Abella, A., Apostolaki, P., Mesnil, B., Politou, C.-Y., Rivoirard, J., Rochet, M.-J., Spedicato, M.-T., Trenkel, V.M., Woillez, M., 2009. Towards an Ecosystem Approach to Fishery Management (EAFM) when trawl surveys provide the main source of information. Aquatic Living Resources 22, 243–253.

Dulvy, N.K., Forrest, R.E., 2010. Life histories, population dynamics and extinction risks in chondrichthyans., *In* Biology of Sharks and Their Relatives. CRC Press, Washington, D.C., pp. 635–675. Ed. by Carrier, J.C., Musick, J.A., Heithaus.

EC, 2009. Green paper: Reform of the Common Fisheries Policy. COM(2009)163. Commission of the European Communities, Brussels.

Ellis, J.R., Dulvy, N.K., Jennings, S., Parker-Humphreys, M., Rogers, S.I., 2005. Assessing the status of demersal elasmobranchs in UK waters: a review. Journal of the Marine Biological Association of the United Kingdom 85, 1025–1047.

FAO, 2003. Fisheries management: 2. the ecosystem approach to fisheries. FAO Technical Guidelines for Responsible Fisheries. 4, 112 pp.

FAO, 2005. Putting into practice the ecosystem approach to fisheries. ISBN 9789251053966. Food and Agriculture Organization, Rome, 82 pp.

Fletcher, W.J., 2005. The application of qualitative risk assessment methodology to prioritize issues for fisheries management. ICES Journal of Marine Science 62, 1576–1587.

Fletcher, W.J., Chesson, J., Sainsbury, K., Hundloe, T.J., Fisher, M., 2005. A flexible and practical framework for reporting on ecologically sustainable development for wild capture fisheries. Fisheries Research 71, 175–183.

Fock, H., 2011. Integrating Multiple Pressures at Different Spatial and Temporal Scales: A Concept for Relative Ecological Risk Assessment in the European Marine Environment. Human and Ecological Risk Assessment 17, 187–211.

Hobday, A.J., Smith, A., Webb, H., Daley, R., Wayte, S., Bulman, C., Dowdney, J., Williams, A., Sporcic, M., Dambacher, J., Fuller, M., Walker, T., 2007. Ecological risk assessment for the effects of fishing: methodology. Report R04/1072. Australian Fisheries Management Authority, Canberra.

Hobday, A.J., Smith, A.D.M., Stobutzki, I.C., Bulman, C., Daley, R., Dambacher, J.M., Deng, R.A., Dowdney, J., Fuller, M., 2011. Ecological risk assessment for the effects of fishing. Fisheries Research 108, 372–384.

Jennings, S., Lee, J., 2012. Defining fishing grounds with vessel monitoring system data. ICES Journal of Marine Science 69, 51–63.

Lynam, C.P., Gibbons, M.J., Bjorn, E.A., Sparks, C.A.J., Coetzee, J., Heywood, B.G., Brierley, A.S., 2006. Jellyfish overtake fish in a heavily fished ecosystem. Current Biology 16, R492–R493.

Lythgoe, J., Lythgoe, G., 1991. Fishes of the sea; the North Atlantic and Mediterranean. MIT Press, Cambridge, Massachusetts. 256 pp.

Marasco, R.J., Goodman, D., Grimes, C.B., Lawson, P.W., Punt, A.E., Quinn II, T.J., 2007. Ecosystem-based fisheries management: some practical suggestions. Canadian Journal of Fisheries and Aquatic Sciences 64, 928–939.

Newell, R.I.E., Ott, J.A., 1999. Macrobenthic communities and eutrophication. *In* Ecosystems at the Land-Sea Margin: Drainage Basin to Coastal Sea. American Geophysical Union, Washington D.C., pp. 265–293. Ed. by Malone, T.C., Malej, A., Harding, L.W., Smodlaka, N., Turner, R.E.

Onley, D., Scofield, P., 2007. Albatrosses, petrels and shearwaters of the world. Helm Field Guides, London. 240 pp.

Peterson, R., Mountfort, G., Hollom, P.A.D., 1983. A field guide to the birds of Britain and Europe. Collins, London. 239 pp. + maps

Pikesley, S.K., Godley, B.J., Ranger, S., Richardson, P.B., Witt, M.J., 2014. Cnidaria in UK coastal waters: description of spatio-temporal patterns and inter-annual variability. Journal of the Marine Biological Association of the United Kingdom doi:10.1017/S0025315414000137

Rees, H.L., Boyd, S.E., Schratzberger, M., Murray, L.A., 2006. Role of benthic indicators in regulating human activities at sea. Environmental Science and Policy 9, 496–508.

Rice, J., Arvanitidis, C., Borja, A., Frid, C., Hiddink, J.G., Krause, J., Lorance, P., Ragnarsson, S.A., Skold, M., Trabucco, B., Enserink, L., Norkko, A., 2012. Indicators for Sea-floor Integrity under the European Marine Strategy Framework Directive. Ecological Indicators 12, 174–184.

Scandol, J., Ives, M., Lockett, M., 2009. Development of national guidelines to improve the application of risk-based methods in the scope, implementation and interpretation of stock assessments for data-poor species. Australian Government FRDC Project No. 2007/016.

Seafish, 2014a, b, c. Ecological risk assessment of the effects of fishing for South West fisheries; ICES Divisions VII e,f,g & h. (a) Seafish Report SR 670. http://www.seafish.org/media/Publications/SR670ERAEFFinal_report1.pdf
(b) Supporting information:
www.seafish.org/media/publications/SR672ERAEFSupporting_information.pdf
(c) Assessment spreadsheet:
www.seafish.org/media/publications/SR671ERAEF_Assessment_spreadsheet.xlsx

Shephard, S., Reid, D.G., Greenstreet, S.P.R., 2011. Interpreting the large fish indicator for the Celtic Sea. ICES Journal of Marine Science 68, 1963–1972.

Shirihai, H., Jarrett, B., 2006. Whales, dolphins and seals. A field guide to the marine mammals of the world. A & C Black, London. 384 pp.

Stobutzki, I., Miller, M., Brewer, D., 2001. Sustainability of fishery bycatch: a process for assessing highly diverse and numerous bycatch. Environmental Conservation 28, 167–181.

Walmsley, S.A., Pawson, M.G., 2007. The coastal fisheries of England and Wales. Part V: a review of their status 2005-6. Science Series Technical Report No. 140. Centre for Environment, Fisheries and Aquaculture Science, Lowestoft, England.

Table 1. Ecological risk assessment terms and abbreviations as used in this paper. Mostly after Hobday et al. (2007).

Term	Meaning	Examples
Activity	Something an agent of change does	Fishing, steaming, nutrient input, dredging, making noise underwater
Agent of change or 'agent'	Something that can affect an ecosystem	A fishery, agriculture, waste disposal, construction works, climate change
Attribute	A feature of a unit of analysis relevant to its survival and role in the ecosystem	Abundance, length composition (for species), area (for habitat), large fish (for a fish community)
Component	Colloquial grouping of related parts of an ecosystem	Teleosts, elasmobranchs, seafloor habitats, ecological communities
Effect or hazard	Change to an attribute of a unit of analysis caused by an activity of an agent of change	Mortality, altered growth, physical disruption, loss of large species
Goal	Top-level policy objective for an ecosystem derived from law, international conventions, or a local political group	'To protect essential ecological processes'
Indicator	A measurable feature of an ecosystem showing its state relative to an operational objective	Catch per unit of effort (CPUE) of mature individuals of a species
Member of a unit	One individual of a unit	one organism, one colony, one separate instance of a habitat or community type
Operational objective	State of an indicator that is consistent with a goal	'CPUE of mature individuals is > X $kg.h^{-1}$' consistent with 'To maintain reproduction'
Relative impact score (RIS)	Geometric mean of spatial (S), temporal (T), intensity (I) and duration (D) scores	$=\sqrt[4]{S.T.I.D}$
Risk	Probability of a hazardous activity preventing achievement of a policy goal	As indexed relatively by RISs.
Unit of analysis or 'unit'	One unit of a component	A stock, a species, a habitat type, a community type

Table 2. Ecological Risk Screening for fisheries off SW England: spreadsheet design used by the ERS WG. a) Columns with prior information about ecosystem components and units of analysis; b) columns filled by the WG.

a) Prior information

Grouping of columns	**Column # and heading**	**Purpose**
Identification and distribution	1. Common name & stock	Identification of unit including name of SW stock if defined
	2. Scientific name	Technical name of the species, or of the habitat/community
	3. Global distribution	Places occupied by the unit, including outside the SW region
	4. Ecology	Notes reminding of main ecological aspects
Status in SW region in 2013	5. SW stock as % of stated stock	Lo/Mid/Hi estimates of proportion of unit (col. 1) within SW region
	6. Selected indicators	Selection from available indicators of the status of the unit
	7. Time trend	Indicators (col. 6) for the unit (col. 1) trending up/down/level?
	8. Information quality	Good/Mid/Poor to indicate the reliability of available indicators
	9. Issues	Notes on ecological, data-reporting, regulatory, rarity or other issues
	10. Information sources	To record consultants' names, references, websites etc.

b) Findings of the ERS WG

Selections by the WG	11. Agent of change	The one of most concern from table 6
	12. Activity	The most risky from table 6. If undecided, extra rows are used
	13. Attribute	The attribute from table 8 of the unit most at risk from the activity
	14. Effect	The most damaging effect on the unit from table 7.
	15. Operational objective (OO)	OO from table 8 and indicator level to achieve goals for the unit
	16. Already achieved?	Whether or not the OO was already achieved, if known
Scores	17. Spatial scale	score 0 to 5
	18. Temporal scale	score 0 to 5
	19. Intensity	score 0 to 5
	20. Duration-of-effect	score 0 to 5
	21. Consequence score	$\sqrt[4]{\text{scores}\,17\times18\times19\times20}$
Adjustments to score	22. Adjusting factors	Text field listing factors that might alter consequences ±0.5
	23. Adjusted consequence	column 21 $\pm$ adjustment from column 22

Table 3. Ecological Risk Screening for fisheries off SW England: fisheries selected for inclusion; descriptive data are approximate. Notes: Many vessels visited > 1 port and fished > 1 gear type; many vessels were part time.

Selected fisheries	**Typical vessel lengths, m**	**Main target spp. and fishing grounds**[1]	**Number of ports used**[2]	**Number of active vessels**			**Notes**
				2003[3]	**2004**[3]	**2005-6**[2]	
Beam trawlers	25 to 30	Sole, plaice, megrim, monk; Channel and SW approaches	6	78	70	100	2 beams ≤ 12m, 80 to 120mm, chainmat or open
Otter trawlers	<10 to 25	Roundfish all around SW peninsula	12	97	102	130	
Scallopers	<10 to 30	Scallops, various grounds in Channel	9	40	48	55	Newhaven dredges, sprung teeth
Potters	Many <10	Lobsters, crabs, inshore	48	65	68	350	Also for whelks[1]
Fixed nets	Inshore: <10; offshore 15 to 25	Various fish, inshore and SW approaches	46	62	46	370	Gill and tangle nets, various mesh sizes
Lines, angling	Many <10	Conger, ling, mackerel, seabass	25	15	24	270	
Ring netters	NA	Pilchard, S coast	NA	NA	NA	NA	Numbers small but unavailable
Pelagic trawlers	NA	Pilchard, scad, seabass	5	10	11	50	

1. Species are: sole=*Solea solea*, plaice=*Pleuronectes platessa*, megrim=*Lepidorhombus whiffiagonis*, monk=mainly *Lophius piscatorius*, roundfish=mainly Gadidae, scallops=mainly *Pecten maximus*, lobster=*Homarus gammarus*, crabs=mainly *Cancer pagurus*, conger=*Conger conger*, mackerel=*Scomber scombrus*, seabass=*Dicentrarchus labrax*, pilchard=*Sardina pilchardus*, scad=*Trachurus trachurus*, whelk=*Buccinum undatum*

2. All vessel sizes; data from Walmsley and Pawson (2007).

3. Vessels $\geq$ 10m Length overall only; data from Cotter et al. (2006).

Table 4. Ecological Risk Screening for fisheries off SW England: principle and policy goals agreed by representatives of fishing and processing industries.

Principle	To leave for future generations the same or better opportunities to benefit from the marine environment around the South West peninsula as the present generation has enjoyed.
Policy goals	1. To maintain an economically viable and regionally diverse fishing industry in South West England. 2. To maintain and protect essential ecological processes and food webs. 3. To avoid taking more fish from a stock than can naturally be replenished. 4. To protect biodiversity including vulnerable marine species and special types of habitat not specifically covered by legislation. 5. To minimise pollution as a consequence of fishing so far as practical and economical. 6. To comply with all legislation applicable to SW fisheries and fish products.

Table 5. Ecological Risk Screening for fisheries off SW England: Ecological components and their units of analysis screened by the WG, plus information sources. Author names in square brackets identify unpublished commissioned reviews (Seafish 2014b). spp.=species.

Component	Unit of analysis	Number of units	Notes	Websites and references consulted
Commercial crustaceans	Species or local stocks	6		[Bell]
Commercial molluscs	Species or local stocks	6	'Squid' (=2 spp.)	marlin.ac.uk; wikipedia.org; iucnredlist.org; [Palmer and Roel]
Elasmo-branchs & Lampreys	Species or local stocks	35	Included coastal, migratory, and deep-sea spp.	iucnredlist.org; fishbase.org; wikipedia.org; ices.dk; iccat.int [Ellis et al.], [Pawson]
Teleosts	Species or local stocks	37	'Shadd' (=2 spp.), 'sea-horses' (=2 spp.), 'gobies' (=2+ spp.), 'monkfish' (=2 spp.)	iucnredlist.org; fishbase.org; wikipedia.org; ices.dk; (Lythgoe and Lythgoe, 1991); [Pawson]; [Catchpole]
Turtles	Species or Atlantic subpopulations.	5	All spp. are migratory vagrants in SW waters	iucnredlist.org; [Penrose]
Marine mammals	Species or local groupings	18	Several spp. are highly migratory and sporadic in SW waters	(Shirihai and Jarrett, 2006); [Kingston, Smout, Northridge]; [Treganza]
Seabirds	Species or local breeding groups	24	Many spp. are present only seasonally in SW waters	(Peterson et al., 1983); (Onley and Scofield, 2007); [Mander, Thomson, Cutts]
Habitats	Types of habitat	9 benthic 1 pelagic	Broad classifications of benthic habitats in SW used	(Jennings and Lee, 2012); [Bolam]; [Koch and Pacitto]
Communities	Types of community	1 fish 3 planktonic 9 benthic		[Bolam]; [Koch and Pacitto]; [Le Quesne]

Table 6. Ecological Risk Screening for fisheries off SW England: Agents of change and summarised activities, shown ✓.

Agents of change	Activities							
	Steaming	**Towing gear on bottom**	**Other fishing activity**	**Discard-ing dead**	**Littering, pollution, gear loss**	**Subsea noise, sonar**	**Other activities**	**Notes**
Beam trawlers	✓	✓		✓	✓	✓		
Otter trawlers	✓	✓		✓	✓	✓		Noise from sounders
Scallopers	✓	✓		✓	✓	✓		
Potters	✓		✓		✓		Bait collection	
Fixed nets	✓		✓	✓	✓		Ghost fishing	Litter from lost gear
Lines, angling	✓		✓	✓	✓		Bait collection	Litter from lost lines
Ring netters, seines	✓		✓	✓				
Pelagic trawlers	✓		✓	✓		✓		Noise from sounders
Shipping	✓				✓	✓	Import of invasive species	Noise from engines etc.
Waste discharges					✓		Pollution	Litter from land
Dredge spoil dumping	✓				✓	✓	Dumping of spoil, rock	Litter from ports
Mineral extraction	✓	✓			✓	✓	Dredging, drilling	Noisy dredges, drills
Construction works					✓	✓	Obstructions	Pile drivers etc.

Table 7. Ecological Risk Screening for fisheries off SW England: generalised possible effects on different ecosystem components of activities of agents of change, and the policy goals for SW fisheries (numbers in brackets, see table 4) that might be at risk, shown ×.

		Policy goals at risk					
Component	**Effect**	**Maintain economic, diverse fisheries (1)**	**Protect ecological processes and food-webs (2)**	**Avoid over-fishing (3)**	**Protect bio-diversity (4)**	**Minimise pollution (5)**	**Comply with legis-lation (6)**
Species or stocks	Direct mortality or injury	×	×	×	×		
	Indirect mortality or impairment	×	×		×		
Habitats	Loss of physical structure or niches	×	×		×		
	Increased mobilisation of sediments	×	×		×		
	Accumulation of dead organic matter		×		×	×	
	Reduced clarity of water		×		×		
	Obstruction of living space or migratory routes	×	×				
	Littering with injurious materials				×	×	×
	Contamination by toxic substances	×	×		×	×	×
	Contamination by underwater noise	×	×		×	×	
	Contamination of air					×	×
Commun-ities	Loss of an important ecological function	×	×		×		
	Loss of an ecosystem service		×				
	Increased frequency of blooms or plagues		×		×	×	
	Simplification of ecological structure		×		×	×	
	Loss of a key supportive species	×	×		×		
	Loss of a rare species				×		×

Table 8. Ecological Risk Screening for fisheries off SW England: Attributes of units of analysis that may be vulnerable to activities of agents of change, and suggested operational objectives and applicabilities in brackets. F=fishing mortality; B=biomass; msy=maximum sustainable yield; CPUE=catch per unit effort (by number or biomass, to be specified); *k* = a reference value; 'surveyed' means subject to quantitative monitoring at sea; <> means < or > as appropriate.

Unit of analysis	Attributes	Operational objectives (and applicabilities)
A species	Abundance (including reproduction)	$F < F_{msy}$; $SSB > B_{msy}$ (modelled species)
		Survey CPUE > *k* (surveyed species)
		Discarded proportion by number < *k* (discarded species)
		Landings or other basic data as a proxy for $B_{msy} > k$ (poorly monitored species)
		Secure presence in SW (rare, resident species)
		Sightings in SW> *k* (rare, migratory species)
		No increase in risk to global population (rare, highly migratory species)
	Growth	Adult CPUE > *k* (measured and surveyed species)
		Proportion of large individuals > *k* (measured species)
		Average condition factor > *k* (weighed and measured species)
	Habitat requirements	No further loss of essential habitat (for benthic, demersal spp.)
		Sediment quality parameter <> *k* (for benthos)
		Water quality parameter <> *k* (for sensitive species)
A type of habitat	Physical structure	No further alteration of physical structure/topography (seabeds)
		No further obstruction of living spaces (seabeds)
	Water quality	Water quality parameter <> *k* (habitat subject to pollution)
	Sediment quality	Sediment quality parameter <> *k* (habitat subject to pollution)
A type of community	Upper size quantile of any species	Proportion of large individuals per species > *k* (fished communities)
	Proportion of large species	Proportion of potentially large species > *k* (fished communities)
	Key species	Key species live securely (any community)
	Diversity of species	Species richness > *k* (sea floor communities)
		Species secure in SW or sighted as expected (rare or key species)
	Foodweb structure	Top predators secure, or their CPUE >*k* (fished communities)
		All trophic levels functioning (depleted communities)
		Diverse trophic functional groups (simplified communities)
	Total biomass	Biomass > *k* (depleted communities)
		Biomass < *k* (communities susceptible to blooms or plagues)
	Ecosystem service	Service effective, e.g. water clarity > *k* (filter feeding communities)

Table 9. Ecological Risk Screening for fisheries off SW England: Summarised list of principal risks of commercial fishing to policy goals (see table 4) as decided by the WG. New abbreviations: U-A=unit-activity; RIS=relative impact score; MLS=minimum landing size; RV=research vessel; CFP=Common Fisheries Policy of the European Union; ASCOBANS=Agreement for conservation of small cetaceans in the Baltic and North Seas. CPR=continuous plankton recorder operated by the Sir Alister Hardy Foundation for Ocean Science.

Ecological component (U-A pairs scored)	**Units with RISs ≥3**	**Main policy goals at risk (table 4)**	**Relevant issues**	**Best available indicators & operational objectives**	**Adjusting factors**	
					Existing management	**Other factors**
Marketable crustaceans (14)	*Palinurus elephas* *Homarus gammarus* *Cancer pagurus* *Maja brachydactyla*	1 (fisheries)	Poorly known growth, mortality rates & ecology	Landings>*k* Spawners per recruit >*k*	✓Closed seasons; MLSs; licensing; soft & berried not landed;	✓High discard survival from pots; no market for small individuals; ✗damage in nets
Marketable molluscs (11)	*Buccinum undatum* *Sepia officinalis* *Pecten maximus*	1 (fisheries) 2 (processes)	Low fecundity, vulnerable eggs Scallops: water clarification	Landings>*k* Observer CPUE >*k*	✓Discards reduced Scallops: rotation of fishing beds, effort controls	
Elasmobranchs (33)	20 species of ray, dogfish & shark	1 (fisheries) 2 (processes) 3 (stocks) 4 (diversity)	IUCN listings, predators, low fecundity	Observer CPUE>*k* Sightings in SW Rays, dogfish: RV survey CPUE>*k*	✓Protection of some spp.; fishery regulations on MLSs, landings	✓May survive discarding; ✗ high vulnerabilities to fishing
Teleosts (24)	14 commercial species	1 (fisheries) 2 (processes) 3 (stocks) 4 (diversity)	Discarding, poorly known biology, vulnerable nursery areas & aggregations, foodweb roles	$F<F_{msy}$, $SSB>B_{msy}$; Landings>*k* 4 spp. only: RV survey CPUE>*k*	✓CFP TACs, effort controls & technical measures giving some improvements,	✓Spatial separation of nursery & fishing grounds or by age & sex; ✗non-UK catches, Pilchard: no management

Table 9, 2nd panel.

Ecological component (U-A pairs scored)	Units with scores ≥3	Main policy goals at risk (table 4)	Relevant issues	Best available indicators & operational objectives	Adjusting factors	
					Existing management	**Other factors**
Sea turtles (5)	*Dermochelys coriacea*	4 (diversity)	IUCN listings; low fecundities, highly migratory; floating litter	Sightings in SW; reduce risks of discarding & littering	×Conservation listings lack legal backing	✓Oceanic ranges imply little impact of fisheries in SW England
Marine mammals (10)	*Tursiops truncatus* *Phocoena phocoena*	2 (processes) 4 (diversity)	Local & migratory spp.; entanglement in fixed nets; top-predator roles	Sightings in SW; 1.7% annual removal rate (ASCOBANS)	✓ASCOBANS; EU reg. 812/2004 on pingers to reduce bycatches	×Pinger trials inconclusive for *Tursiops*
Habitats (0)	No habitats were considered	2 (processes) 4 (diversity)	Distributions poorly known; Priority listings of special habitats in SW region		✓UK Biodiversity Action Plan	×Impacted by aggregate extraction, dredge-spoil dumping; construction works
Communities (16)	Demersal fish; ichthyoplankton; 3 epibenthic com-munities	1 (fisheries) 2 (ecology) 3 (stocks) 4 (diversity)	Already highly modified by fisheries; ichthyoplankton & fish linkages	Size-based indicators →trophic functioning; CPR-based indicators	✓CFP controls benefiting some fish spp.	×Impacted by non-UK fishers & non-fishing activities

Figure 1. The SW marine ecosystem (ICES VIIe-h) defined for the purposes of ecological risk screening conducted in 2013. The darkened coastline indicates the moorings of included fisheries.

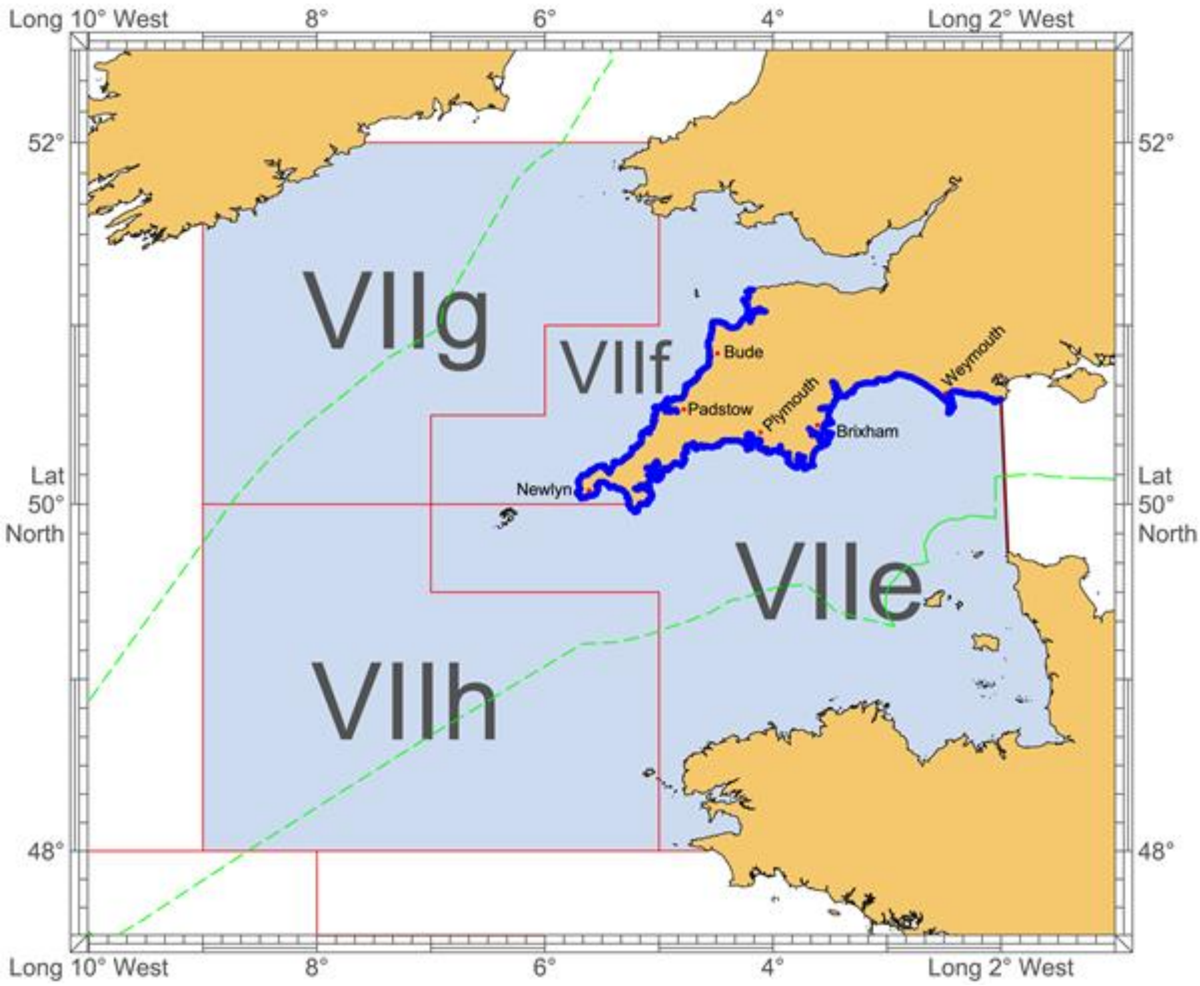


Figure 2. Ecological risk screening: flow diagram for choosing unit-activity (U-A) pairings with highest relative impact scores. Ind = indicator, OO = operational objective, RL = reference level, …. = continuation of list.

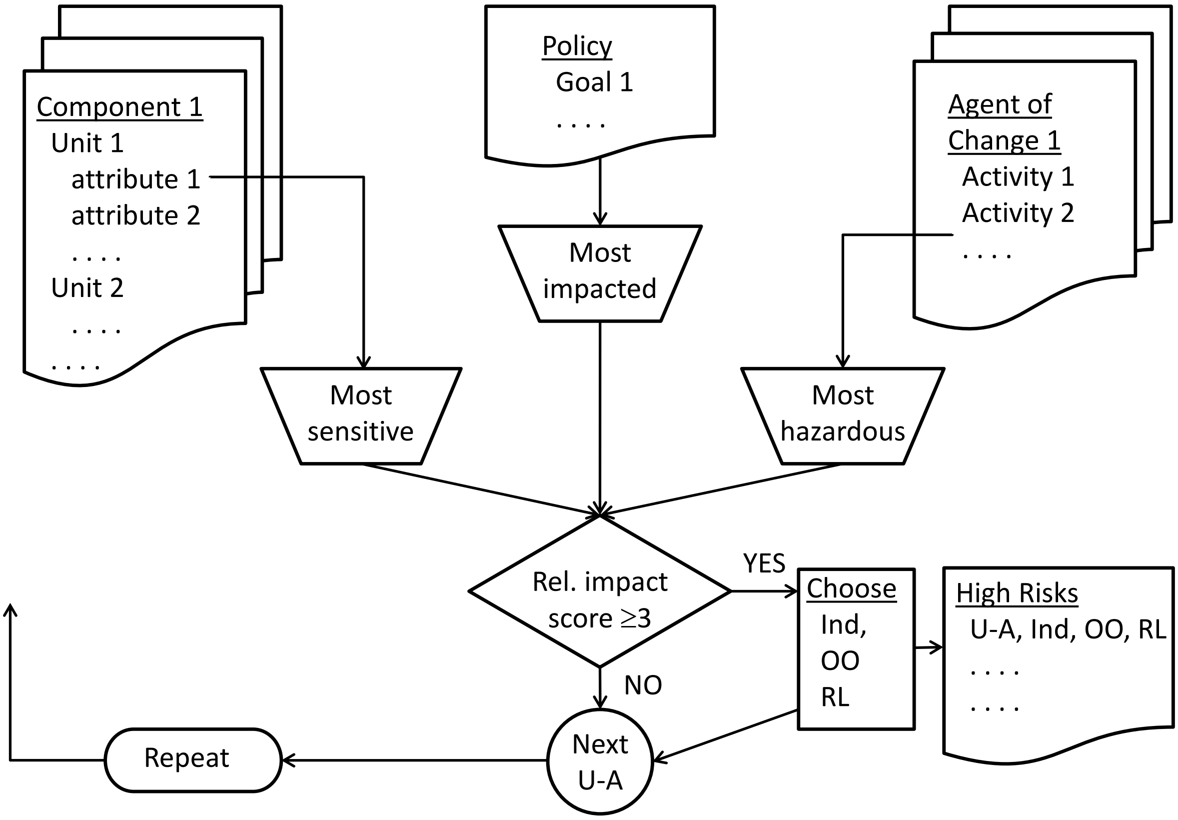
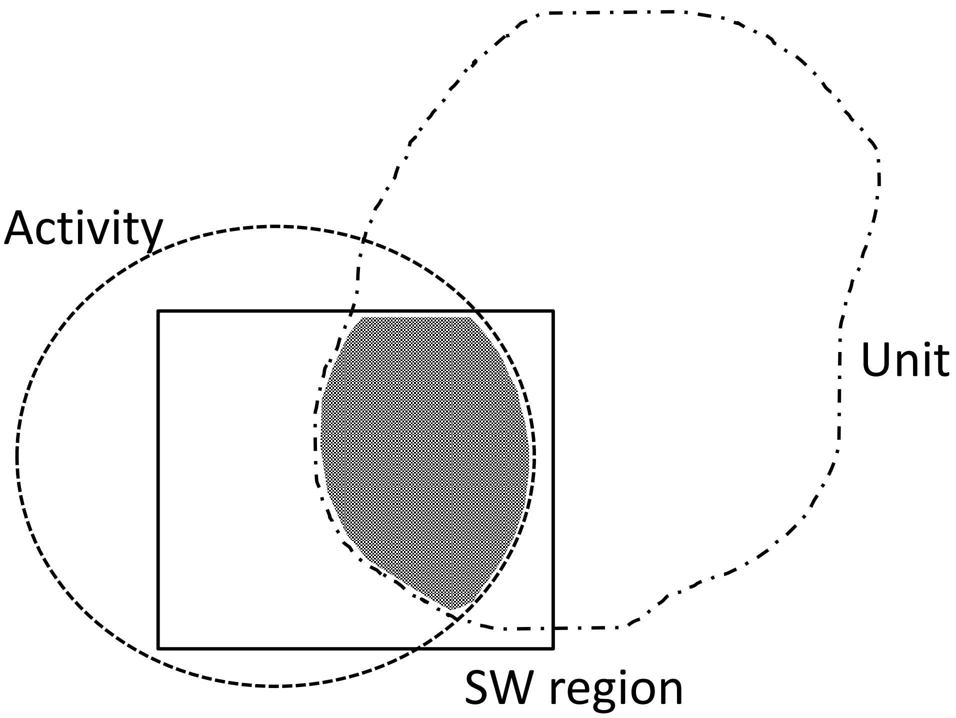


Figure 3. Ecological risk screening for fisheries off the SW of England; two scoring systems used. a) Spatial score is the intersection (grey) of the area of activity (dashes), the area occupied by the unit (dot-dashes) while the activity is occurring, and the SW region (rectangle), expressed as a fraction of the total area occupied by the unit (which, if the unit is migratory, may be larger than the dot-dashed region). b) Temporal score is the length of the grey arrow as a proportion of a year for perennial species. The lifespan of vulnerable stages is used instead of 1 year for annual species.



b)